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Coeur d'Alene, Idaho

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TITLE

STATUS AND EFFECT OF A MOUNTAIN PINE BEETLE INFESTATION ON LODGEPOLE PINE STANDS

SUBJECT—

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Forest Insect Investigations
Coeur d'Alene, Idaho

May 18, 1943

To: F. C. Craighead, in Charge, Forest Insect Investigations

From: James C. Evenden, in Charge, Coeur d'Alene Laboratory

Subject: Report "Status and Effect of a Mountain Pine Beetle Infestation on Lodgepole Pine Stands", by A. L. Gibson

I am enclosing a copy of a report by Mr. Gibson entitled "Status and Effect of a Mountain Pine Beetle Infestation on Lodgepole Pine Stands". This report summarizes the data obtained from a series of sample plots and strips which were set out some years ago for the purpose of recording what actually happens to a lodgepole pine stand when it is invaded by a serious epidemic of the mountain pine beetle. As yet the complete story is not told. It is also realized that some changes may be necessary in the type of data obtained during subsequent examinations. However, with these data, which depict the original stockings on each plot, the final story can be told when subsequent findings are made available. Your comments concerning this report, which serves the primary purpose of bringing Mr. Gibson's data up to date, will be greatly appreciated.

Copies of this memo and the report have been sent to Keen, Furniss, and Wygant, and a copy has been routed through the eastern stations.

James C. Evenden

Enclosure

STATUS AND EFFECT OF A MOUNTAIN PINE BEETLE INFESTATION ON LODGEPOLE PINE STANDS

INTRODUCTION

The mountain pine beetle caused increasing losses to vast areas of mature lodgepole pine from 1925 to 1933. Limited areas had suffered heavy depletion prior to that time, but during the latter part of the aforementioned period the outbreaks became general over about 20,000 square miles. In many areas practically all merchantable lodgepole pine had been killed and heavy losses had occurred in young trees to as low as 6 inches d.b.h.

At the time of this outbreak the chief concern was over the destruction of the vast stands of mature lodgepole pine. They constituted a valuable asset in accessible areas, especially where they adjoined the ready market of mines. Large quantities were used for props and stulls, railroads were heavy users for ties, and local communities frequently depended largely upon them for home construction material and fuel. The immediate or direct loss to the lodgepole pine stands was high, but indirect losses, subsequent to the cessation of the outbreak, are proving to be considerable and persisting over a long period of time. These indirect losses are as follows:

(1) Attack by secondary bark beetles.*

(2) By overthrow or breakage of remaining living timber from windthrow of dead trees.

(3) Windthrow and breakage of remaining living trees as a result of opening up of the stand.

Direct losses limited to trees attacked by the mountain pine beetle have been light since 1933, but indirect losses are continuing and will persist for many years. The latter consist in part of the killing by secondary bark beetles of many of the trees weakened by unsuccessful mountain pine beetle attacks. In addition to the preceding, another indirect effect arises from the windthrow of bark-beetle-killed trees. This opens up the stand, causing windthrow and breakage of many of the surviving tall, slim trees. Snow breakage increases under the above conditions, due in part to heavier snow burden by the remaining slim trees and also to lack of support previously afforded by adjoining trees, now dead. Fall of dead trees not infrequently results in the overthrow of

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* Chiefly Ips oregoni, Pityogenes knechteli, and Pityophthorus burkei.

a living tree or trees. An even greater number are more or less seriously injured by scraping of the bark from the bole, breaking of limbs and tree tops. This damaged material is almost invariably attacked by secondary bark beetles, which are attracted in such numbers they usually complete the destruction of the weakened tree. If activity of these secondary insects was limited to this damaged material, it would not be serious. However, they usually invade neighboring undamaged trees as well, resulting in the formation of a more or less large hole in the crown canopy if the stand is of tall, slim poles. Under such condition further losses among the adjoining trees may be expected.

It is readily seen that indirect losses can continue over a long period. It is to secure some measure of these delayed effects that intensive studies have been undertaken. They are of entomological, economic and silvicultural interest. The first has been briefly discussed. In the second phase, the economic, it is important to know the losses in merchantable timber that have occurred, the problems concerned with administrating a bark-beetle-devastated area, and what influence the changed stand will have on the local economy. In the third phase we are concerned with the changes in stand growth, yield, and composition. Usually the destruction of mature timber has been too great for the remainder to be attractive to large-scale woods operations. Profound changes may occur in the composition of the stands with the disappearance of so large an amount of one timber species. The future timber stand may be decidedly influenced in value by composition changes.

In addition to the preceding, maintenance costs have greatly increased where the falling trees block roads and trails and break down telephone lines. Fire hazard increases as "jack-straw" conditions develop in areas formerly covered with a heavy stand of mature timber. Deterioration of fallen timber under the above conditions is slow, resulting in a long-time fire hazard.

The record of the changes in a stand during and following a mountain pine beetle infestation have been kept chiefly by means of sample plots and strips on four different national forests, the Bitterroot, Beaverhead, Targhee, and Gallatin. The sample plots on the Bitterroot have been the source of the more intensive data obtained, whereas chiefly stand loss estimates were derived from the sample strips. Woodcutters have so interfered with stand conditions on the Targhee check strip as to render future data from it of little value, necessitating its abandonment. On the Gallatin, strip losses have been comparatively light in lodgepole pine but heavy in the whitebark pine. On the Beaverhead, part of the data is from two areas which were suffering increasing losses up to the time the outbreak suddenly decreased. On a third area the outbreak had largely run its course and was decreasing because of lack of host material at the time natural factors caused a sudden cessation of the outbreak. On the Bitterroot plots the infestation ran its course and is believed to represent the natural development of an outbreak. As this occurred on the Bitterroot at an earlier time than on the Beaverhead, Gallatin, and Targhee Forests, post-outbreak losses have been occurring over a longer period of time and have been heavier.

It was with the desire to secure some index of the various changes that have occurred and will occur that the studies have been conducted. The data and analyses are presented for each strip or plot in the following pages. In spite of different general conditions, some similarities result in a duplication of explanations and conclusions.

LOSSES DUE TO THE MOUNTAIN PINE BEETLE

THE BATTLEFIELD CHECK STRIP

Possibly the heaviest losses have occurred in the general region south from the headwaters of the East Fork of the Bitterroot River and including that part of the Beaverhead National Forest which adjoins the Big Hole Basin. A strip was located at the Battlefield near Wisdom, Montana, near the northwest part of this region. Originally the plot was established to study percentage of total attack present at various times during the field season. Located at elevations ranging from 6900 to 7500 feet, it is fairly representative of stand conditions over a large part of the region just discussed.

The strip was covered with a dense stand of almost pure lodgepole pine of varying age and maturity, ranging from reproduction over limited areas to others supporting only mature trees. To give a clear picture of the preference of the mountain pine beetle for trees of the larger sizes, your attention is called to columns 3 to 7 in table 1-a, which gives the losses by two-inch classes.

Table 1-a - Timber stand on the Battlefield check strip before and after the mountain pine beetle infestation - showing direct and indirect losses - data to and including fall of 1940 - acreage of strip 36

Number of trees

Column	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
DBH	Living prior to outbreak: LP	Living prior to outbreak: DF	Bark-beetle attacked LP	Which pitched-out D.m. attack	Green-sided from: D.m. attack	Killed by D.m. & 1/: D.m.	Killed by D.m. & 1/: Sec.	Killed by D.m. & 1/: Sec.	Indirectly killed by outbreak: Snowbreak: DF	Snowbreak: LP	Wind: DF	Wind: LP	Falling D.m. killed trees: DF	Falling D.m. killed trees: LP	Living in remaining stand: DF	Living in remaining stand: LP 2/
2	19,726	476	384		1	2	10	371	4	35	4	43	5	32	463	19.232
4	9,875	114	1,112			442	198	472	2	12	2	15	1	13	109	8.723
6	6,447	76	3,756	1,266		1,557	365	568	1	1		4	2	10	73	3.942
8	4,431	29	3,743	1,247	410	1,691	187	208				4			29	1.931
10	1,872	38	1,701	31	162	1,425	42	41			3	3		1	35	198
12	615	10	615			592	22				1	1			9	--
14	342	9	342			332	10				1				8	--
16	38	--	38			38						1			--	--
18	29	--	29			29									--	--
20	--	10	--												10	--
22	1 3/	9	1 3/			1 3/									9	--
	43,376	771	11,720	2,544	573	6,109	834	1,660	7	48	11	71	8	56	746	34,026

1/ The secondary bark beetles were chiefly Ips oregoni, Pityophthorus burkei, and Pityogenes knechteli.

2/ Includes "pitched-out" trees, which are little if any impaired in timber value.

3/ Western yellow pine.

Table 1-b - Windthrow of mountain-pine-beetle-killed lodgepole pine

Year windthrown:	1936			1937					1938					1939					1940				
Year killed	Pre 31	32		Pre 31	31	32	33	34	Pre 31	31	32	33	34	Pre 31	31	32	33	34	Pre 31	31	32	33	34
Number of trees:	5	1		30	14	12	5	1	41	14	18	7	1	23	21	18	7	1	47	27	20	19	4
Total		6					62					81					70					117	
																						336	

Inspection of columns 1, 3, 5, 6, 7 and 8 reveals the comparative immunity of the smallest diameter class to either mountain pine beetle or secondary bark-beetle attack and also shows the increase in susceptibility with increase in diameter. Many of the smallest trees were only attacked by secondary insects because they had been previously weakened by some other agency. This comparative immunity prevailed even though intensity of attack had been extremely high in the region represented by this strip. It is believed the following brief tabulation will indicate the maximum percent of losses in the various diameter classes that can be expected from severe epidemics in lodgepole pine stands. Losses due to secondary bark beetles are continuing so the data for their activity is incomplete but are presented for what they show up to 1940.

Susceptibility of D.b.h. 2-inch classes of lodgepole pine to mountain pine and secondary bark beetle attack, as indicated by data from Battlefield check strip - Beaverhead 1940

Percent of the number in each class successfully attacked						
D.b.h. classes	2	4	6	8	10	12+
By D.a.	.1	6.5	27.5	56.5	87	100
By sec. 1/	1.5	5.0	9.0	5.5	1.5	none

1/ Continuing.

In further reference to table 1-a, it must be pointed out that columns 7 and 8 would probably contain a smaller proportion of total kill and column 5 a larger proportion, had it not been for the sudden decrease of the mountain pine beetle in 1933. This decrease left a tremendous number of secondary bark beetles, with only a fraction of the necessary "ready made" host material they had had in such abundance while the outbreak was increasing. As a result, many of the trees attacked by the mountain pine beetle in 1933 were immediately "filled in" by secondary bark beetles. Also in many small trees these secondaries assumed a primary role in 1933 and 1934.

The more than 2500 trees on the strip which "pitched out" attack are not considered as part of the loss because such trees are seldom sufficiently damaged to prevent their making acceptable future timber. On the other hand, green-sided trees are considered as loss because most of them are soon killed by secondary bark beetles or, due to rot at the base of the dead side of the tree, are eventually windthrown.

Direct losses were negligible on this strip after 1933, but indirect loss had continued from secondary insects. In 1936, other sources began causing increasing losses. Some idea of the amount of it is seen in columns 9 to 14 of table 1-a. Up to 1940 these indirect losses amount to 24 percent of the total number killed, but owing to the small diameter of the trees involved they comprise only 8.2 percent of the total basal area loss. While an estimate is subject to considerable inaccuracy, losses from falling bark-beetle-killed trees can be expected to continue on the same general scale as in the past. In addition to the preceding, windbreak and snowbreak, from opening up of the stand, are also expected to continue to cause more or less loss. Similarly, based on what has occurred up to the present time, it is believed total losses from indirect sources will finally equal about one-half the number of trees and 16.5 percent of the total basal area loss.

Windthrow of bark-beetle-killed trees increases the cost of maintaining roads, trails, and telephones. To know how soon after an outbreak need for additional maintenance may be expected it is important that the period between kill and windthrow of these trees be obtained. Also the percent that fall each year and the duration of this period of fall is needed. In table 1-b these data are given for the Battlefield strip up to 1940. The shortest period between kill and windthrow was 3 years, for one tree of the 336 windthrown to 1940. The average period between kill and windthrow was 7.6 years up to 1940. However, as only 336 of over 9000 trees have been windthrown, this average will be raised. It has been found that some trees will stand for at least 15 years.

Due to the selection of the larger trees in a stand by the mountain pine beetle the number of trees killed on the strip is not a true index of the severity of the losses. Basal area of killed and surviving trees pictures much more clearly the stand depletion. Table 2 gives the losses on that basis.

Table 2 - Timber stand on the Battlefield check strip before and after the mountain pine beetle infestation - showing direct and indirect losses - data to and including fall of 1940

Basal area

Columns	1	2	3	4	5	6	7	8	9	10	11
	Living trees on strip				Losses on strip [2]				Total losses		LP only
	Prior to outbreak		As of 1940						to		% loss in each
D.b.h. classes	LP	DF	LP [1]	DF	To LP from D.m.&sec.	To LP from Sec.	Indirectly LP	Indirectly DF	LP	LP & DF	D.b.h. class is of total loss
2	433.97	10.47	423.10	10.19	0.29	8.16	2.42	.28	10.87	11.15	.3
4	869.00	10.03	767.62	9.59	56.32	41.54	3.52	.44	101.38	101.82	3.0
6	1,270.06	14.97	776.58	14.38	378.63	111.90	2.95	.59	493.48	494.07	14.8
8	1.537.56	10.07	670.05	10.07	793.94	72.18	1.39	--	867.51	867.51	26.0
10	1,020.24	20.72	107.91	19.09	887.80	22.35	2.18	1.63	912.33	913.96	27.3
12	482.77	7.85	--	7.07	481.99	--	.79	.78	482.77	483.55	14.5
14	365.26	9.61	--	8.54	365.26	--	--	1.07	365.26	366.33	10.9
16	53.05	--	--	--	53.05	--	--	--	53.05	53.05	1.6
18	51.24	--	--	--	51.24	--	--	--	51.24	51.24	1.5
20	--	21.84	--	21.84	--	--	--	--	--	--	
22	2.64	23.76	--	23.76	2.64	--	--	--	2.64	2.64	.1
Totals & averages	6,085.79	129.32	2,745.26	124.53	3,071.16	256.13	13.25	4.81	3,340.53	3,345.32	54.9

[1] Includes "pitched-out" attack trees.

[2] Includes "green-sided" trees.

Comparison of figures in columns 1 and 5 of table 2 shows the losses by 2-inch diameter classes. Inspection of column 3 reveals no living basal area in lodgepole pine above the 10-inch class.

The stand per acre was reduced from 1,226 to 965 trees in 1940 and will probably be lowered to 875 by the time all indirect losses have occurred. These figures, however, include only timber which came within the lowest diameter classification at the time of the outbreak. Since then many of the smaller trees have increased in size, so they now fall within the lowest diameter classification. Also, increase in diameter growth has been sufficient to raise a small percentage of each 2-inch class into the next higher diameter class, thus slightly raising the average diameter as well as the total number of classified trees.

Changes in Stand Composition

Prior to the mountain pine beetle outbreak, Douglas fir and other tree species comprised only 2.7 percent of the number and 2.9 percent of the basal area of the total timber stand. While Douglas fir and alpine fir are not subject to mountain pine beetle attack, these tree species have suffered some indirect losses due to the outbreak. In spite of that, these two species comprised 3.9 percent of the number and 5.1 percent of the basal area of the remaining living stand in 1940. However, these figures are only partly indicative of the timber type changes which are occurring on the parts of the strip which have suffered serious depletion of the lodgepole pine. Although only scattered seed-producing trees are present, Douglas fir, to a lesser extent alpine fir, and a few Engelmann spruce have already contributed much more than 3.9 percent of the seedlings and reproduction coming up on the strip. This increase was quite apparent in the period from 1936 to 1940. The future stand should contain an even higher percentage of tree species other than lodgepole pine.

Fire Hazard

The vast amount of dead timber on the strip, which is representative of a large area, constitutes a serious fire hazard. Windthrow of the thousands of dead trees will increase this hazard. Deterioration of the "jack-straw" masses of timber is slow, which means that fire danger from such areas will continue for many years. Maintenance of telephone lines, roads, and trails will be expensive and difficult, resulting in a high protection cost for a low present timber valuation. High maintenance costs may be expected for a period dependent upon how rapidly the standing dead trees windthrow and indirect losses persist.

WISE RIVER CHECK STRIP

This 40-acre strip had not been subjected to as heavy loss from the mountain pine beetle outbreak as the timber stands a few miles further west. In addition, other tree species, especially Douglas fir, comprise a much larger part of the stand than is present on the other strips. The presence of the highest ratio of Douglas fir to lodgepole pine of any of the three strips on the Beaverhead is believed to be largely due to this strip being at the lowest elevation, 6400 to 7300. Because of the greater amount of other tree species the loss of some lodgepole pine in this mixed type could not be expected to have as drastic an effect upon the stand as the destruction of an equal ratio of that species in pure lodgepole pine.

No direct losses from the mountain pine beetle outbreak were noted on this strip between 1937 and 1940. Indirect loss from secondary bark beetle activity, however, has continued. They attacked chiefly the trees damaged by falling dead trees, those windthrown, and others broken by snow. The apparent recent increase in losses from the latter two sources is believed to be due to opening up of the stand following loss of foliage from the large number of dead trees and from windthrow of a few of them. Increase in windthrow of these dead trees will open up the stand still more and probably further increase windthrow of the remaining green trees. The preceding conditions should keep secondary bark beetles supplied with an above-normal amount of host material for a number of years.

The status of the stand in 1940 and the losses which have occurred to that date are shown in table 3.

Table 3 - Stand losses on the Wise River check strip directly and indirectly due to mountain pine beetle activity
1940

		Stand on strip		
		Total	Per acre	Aver. d.b.h.
1.	Lodgepole pine prior to outbreak - over 1" d.b.h.	20,919	523	4.2
2.	Remaining lodgepole pine over 1" d.b.h.	18,410	460	3.7
3.	Douglas fir and other species	7,207	180	4.9
4.	Killed by mountain pine beetle	1,577 1/	39.4	9.9
5.	Killed by mountain pine beetle and secondary insect attack	272	6.8	8.1
6.	Killed by secondary insect attack only	542 2/	13.5	4.1
7.	Windthrown mountain-pine-beetle-killed lodgepole pine - 1936-1, 1937-9, 1938-15, 1939-14, 1940-28	67	1.7	9.1
8.	Killed by windthrow and snowbreak - 1938-6, 1939-42, 1940-53	101 3/	2.4	2.7
9.	Killed by falling bark-beetle-killed trees	8	.2	3.0
10.	Undamaged trees killed by secondary bark beetles since 1937	21	.5	3.9
11.	DF and other species now 46.1% of basal area			
12.	LP now 53.9% of basal area.			
13.	LP now 71.9% of total trees on area.			
14.	DF and other species now 28.1% of total trees on area.			

1/ No losses after 1936.

2/ Began in 1933 - includes 2" d.b.h. class and up.

3/ Includes 4 Douglas fir.

Inspection of table 3 reveals that the losses caused or contributed to by secondary bark beetles, as shown in items 5, 6 and 10, amount to 814 trees, or 32.6 percent of the 2,500 trees killed on the strip. Losses by windthrow and snowbreak already amount to 109 trees, or 4.4 percent of the total losses. Of the total losses, those directly caused by the mountain pine beetle numbered 1,577 trees. Indirect losses, which have occurred largely since the cessation of the mountain pine beetle outbreak, have already amounted to 60 percent of the number from that source, are continuing, and may be expected to continue for a number of years. However, it must be pointed out that these indirect losses are usually in the small-diameter trees whose average basal area is only about 1/3 that of the trees killed by the mountain pine beetle. The size of the trees killed both directly and indirectly as a result of the mountain pine beetle outbreak are shown in table 4-a.

The length of time mountain-pine-beetle-killed timber remains standing in this mixed type stand is shown in table 4-b. The strip was not established until 1931, but as only 184 trees were killed that year, loss prior to 1931 is hardly likely to have been in excess of 75 trees for the entire strip, and at least 50 of that number were probably killed in 1930. For the purpose of this study we may therefore consider 1930 as the average date of kill of trees by the mountain pine beetle on this strip prior to 1931. The average date when killed was late 1931; year of fall, late 1938; or an average at the end of 1940 of slightly over 7 years from year killed until they fell. As only a small percent of the total trees killed have fallen, this average will increase.

Table 4-a - Summary of annual losses due directly and indirectly to mountain pine beetle - Wise River check strip, Beaverhead National Forest - data to 1940 - acreage of strip = 40

	Direct losses										Indirect losses													
	LP killed solely by MPB and by both MPB and secondary bark beetles										LP killed by secondary bark beetles							LP killed by falling trees		LP killed by windthrow and snowbreak			
Inches d.b.h.	2	4	6	8	10	12	14	16	18	24	2	4	6	8	10	12	14	2	4	2	4	6	8
Year killed																							
To 1933	4	19	177	579	393	315	157	26	19		18	16	12	5	1	4	3						
1934		3	29	52	19	12	5				182	121	68	26	7	3	1						
1935		1	4	10	1	1				1	10	8	6	1		3							
1936			2	9	6	1	1				13	10	2	1									
1937														1									
1938											3	2		2						2	4		
1939																						1	DF
"											8	3	1		1			2	2	27	9	3	2
1940																				2	DF 1	DF	
"																		2	2	43	7		
Totals	4	23	212	650	419	332	163	26	19	1	234	160	89	36	9	10	4	4	4	74	21	4	2
Series totals									1,849								542		8				101

Table 4-b - Windthrow of mountain-pine-beetle-killed lodgepole pine

Year windthrown	1936		1937			1938				1939				1940					
Year killed	Pre 31		Pre 31	31	32	Pre 31	31	32	34	Pre 31	31	32	34	Pre 31	32	33	34	36	40
Number of trees	1		6	2	1	10	3	1	1	4	2	7	1	11	4	5	6	1	1
Total	1				9				15				14					28	
Grand total																			67

Changes in Stand Composition

The comparatively light loss in this mixed stand has caused little change in the ratio of immune and susceptible tree species prior to and subsequent to the outbreak. The increase in immune species was only 2.5 percent, from 25.6 to 28.1. In basal area, however, the loss of the larger diameter lodgepole pine raises the percent of the immune species from 34.7 to 46.1, an increase of 11.4 percent. From this increase in basal area it is seen that the future volume of the stand will be practically half other species than lodgepole pine. Douglas fir comprises about 80 percent of the immune species, the remaining 20 percent being chiefly alpine fir and Engelmann spruce.

Had it not been that the outbreak was suddenly arrested just at the time it was beginning to cause serious losses on this area, the lodgepole pine would have been much more seriously depleted and the immune species left as a much larger ratio of number and volume of the residual stand. The effect of the shorter duration of the outbreak on the area represented by this strip is seen in the much lighter losses in the smaller-diameter classes and considerable survival even of the large trees.

THE ELKHORN CHECK STRIP

Losses from the mountain pine beetle outbreak have been the lowest on this strip of the three on the Beaverhead Forest. The advancing outbreak was just beginning to cause heavy losses in the area when natural factors brought it under control. Considerable timber of larger diameter still survives. The stand is similar to that on the Battlefield strip in that its composition is almost pure lodgepole pine, but differs in having fewer trees of the 6- to 14-inch diameter classes and in being located at a higher altitude range, from 7,200 to 7,950.

Windthrow of mountain-pine-beetle-killed trees started in 1937, but has been as light as on the Wise River strip up to 1940. The average year for death of the trees was 1933. Data secured up to 1940 show there is an average of 7 years from kill to overthrow, the same as that on the Wise River strip. Data concerning windthrow of bark-beetle-killed trees are shown in table 6-b. The data summarizing direct and indirect losses on the Elkhorn strip are given in table 5.

Table 5 - Losses on the Elkhorn check strip directly and indirectly due to mountain pine beetle activity 1940

		Stand on strip		
		Total	Per acre	Aver. d.b.h.
1.	Lodgepole pine prior to outbreak 2" d.b.h. and over	37,582	1,044	3.8
2.	Remaining lodgepole pine 2" d.b.h. and over	34,259	952	3.6
3.	Douglas fir and other species 2" d.b.h. and over	437	12.1	2.7
4.	Killed by mountain pine beetle	710	19.7	11.2
5.	Killed by mountain pine beetle and secondary attack	164	4.6	9.2
6.	Killed by secondary insect attack only	1,215	33.7	3.9
7.	Windthrown mountain-pine-beetle-killed lodgepole pine, 1937-8, 1938-3, 1939-16, 1940-33	60	1.7	7.3
8.	Killed by windthrow and snowbreak, 1937-8, 1938-2, 1939-5, 1940-23	38	1.1	3.4
9.	Killed by falling bark-beetle-killed trees, 1937-1, 1939-2, 1940-5	8	.2	2.2
10.	Undamaged trees killed by secondary bark beetles, 1937-17, 1938-33, 1939-63, 1940-36	149	4.1	3.9

11. DF and other species now 1.6% of basal area.

12. LP now 98.39% of basal area.

13. LP now 98.65% of total trees on area.

14. DF and other species now 1.26% of total trees on area.

An inspection of the data shows that the average stand per acre has been reduced only about 9 percent, with of course much heavier losses in mature timber and comparatively little among the small poles and saplings. Trees in which the primary cause of death has been the mountain pine beetle number 874, in contrast to 1,253 killed by secondaries and other causes. The total basal area of the 1,253, however, is only about 28 percent of that of the trees whose death was directly caused by the mountain pine beetle.

Further indirect losses may be expected in the lodgepole pine from damage caused by the fall of the insect-killed trees and from increases in windthrow and snowbreak. This constant supply of host material for secondary insect attack will stimulate further losses because of the tendency of these insects to "boil over" into undamaged trees.

The losses attributable to each source, up to 1940, on the Elkhorn check strip, are shown in table 6-a. A glance at the data presented reveals the selection of smaller-diameter trees by secondary bark beetles where the trees are undamaged. On weakened trees they do not seem to be so selective.

The attack of young trees in dense stands may be beneficial in some instances, by reducing overcrowded conditions. However, the tendency to kill too many, if not all the trees in a small area, makes a hole in the crown canopy, which is often followed by more or less windthrow and snowbreak of the tall, slim trees bordering such openings. Such conditions have developed in a number of places on the Elkhorn strip.

Table 6-a - Summary of annual losses due directly and indirectly to mountain pine beetle - Elkhorn check strip, Beaverhead National Forest - data to 1940 - acreage of strip = 36

	Direct losses												Indirect losses														
	LP killed solely by MPB and by both MPB and secondary bark beetles												LP killed by secondary bark beetles							LP killed by falling trees		LP killed by windthrow and snowbreak				
Inches d.b.h.	2	4	6	8	10	12	14	16	18	20	22	26	2	4	6	8	10	12	14	2	4	2	4	6	8	10
Year killed																										
To 1933	1	-	54	125	113	140	92	53	19	7	-	8			3	2	1									
1934		3	15	36	82	45	10	3	1	1			333	163	104	63	36	12	4							
1935		2	2	14	5	3	3						141	55	27	7	4	1								
1936		2	9	5	7	3	1						41	43	12	10	2									
1937			1		1								5	3	5	1	2	1		1						
1938			3		1	1	1	1			1		15	8	6	3	1						2			
1939																			27							
"													30	25	9				41	1	1	2	3			
1940													22	8	4	1	1			5		18	2		1	2
Totals	1	7	84	180	209	192	107	57	20	8	1	8	587	308	169	86	46	14	441	7	1	20	7		1	2
Series totals											874								1215		8					30

Table 6-b - Windthrow of mountain-pine-beetle-killed lodgepole pine

Year windthrown	1937						1938				1939						1940				
Year killed	Pre 32	32	32	33	34	37	Pre 32	32	32	33	Pre 32	32	32	33	34	35	32	33	34	35	36
Number of trees	3		2	1	1	1	1		1	1	5		5	2	3	1	12	2	7	11	1
Totals						8				3						16					33

Inspection of table 6-a reveals secondary insects have not only killed a surprisingly large number of small trees but they are still active on this strip in contrast to little activity on others. However, falling trees and other indirect losses had made but slight inroads on the remaining green stand up to 1940.

Change in Stand Composition

This plot has an even nearer approach to a pure lodgepole pine stand than the Battlefield strip. With but a slight mixture of other species and comparatively light losses of lodgepole pine, stand composition has remained practically unchanged. On limited areas of the strip where losses have been heavy, considerable reproduction of Douglas fir, alpine fir, and a few Engelmann spruce is"coming in", but there is no indication that these species will "take over" the stand in the near future or become even an important part of it.

THE SQUAW CREEK CHECK STRIP

In 1941, losses on the Squaw Creek check strip were quite light. Although the same number of lodgepole pine were attacked by the mountain pine beetle as in 1940, the population of insects was much lighter per tree. Secondary insects had "filled-in" more bark surface than the primary insect had invaded.

Losses from other sources than insects amounted to one-third of the total killed on the strip. The losses are shown in table 7.

Table 7 - Losses on Squaw Creek check strip on Gallatin National Forest in 1941

Attacking bark beetle	Number of trees					
	Killed		Green-sided		Pitched-out	
	No.	Per acre	No.	Per acre	No.	Per acre
Mountain pine beetle in lodgepole pine	1	.03	3	.08		
Mountain pine beetle in whitebark pine	4	.11	2	.05	1	.03
Secondaries in lodgepole pine	16	.44	1	.03	--	
Secondaries in whitebark pine	5	.14	--		--	
Douglas fir beetle in Douglas fir	2	.05	--		--	
Secondaries in Douglas fir	1	.03	--		--	
Western balsam bark beetle in alpine fir	3	.08				
Losses due to action of wind and snow						
Lodgepole pine	10	.28				
Whitebark pine	2	.05				
Douglas fir	1	.03				
Engelmann spruce	1	.03				
Alpine fir	2	.05				
	48	1.33	6	.16	1	.03

Inspection of table 7 reveals losses attributable to the mountain pine beetle to be only about one-third of the total in lodgepole and whitebark pine due to all bark beetles. The data indicate a decrease in mountain pine beetle activity in the strip over the preceding year, especially in whitebark pine. In lodgepole pine the mountain pine beetle has apparently decreased to a normal status, having caused about the same losses for the period from 1937 to 1941. In whitebark pine it has showed a marked decrease with less than half as many trees attacked in 1941 as in 1940.

The Douglas fir beetle was found in two trees on the strip in 1941 compared with only one in 1940, but one tree attacked in 1941 had been windthrown. Therefore, although light epidemic in character, we may consider the activity of this insect to be about the same for the two years. General observations on other parts of the forest indicate a slight decrease in trees attacked.

The Engelmann spruce beetle epidemic of a few years ago seems to have died out. Alpine fir continues to show some loss from the western balsam bark beetle.

The region of which the Squaw Creek check strip is representative has been but lightly devastated by the mountain pine beetle in the lodgepole pine type. Direct losses due to this insect amount to an average of 1.47 trees per acre. In whitebark pine it has amounted to an average of 3.66 trees per acre during this same period from about 1930 to 1941. The kill in whitebark pine is much heavier than the data indicate because the losses are concentrated on a small acreage. Furthermore, that amount of loss is much more serious in whitebark pine stands because they are quite open, in contrast to the dense stands characteristic of lodgepole pine. Whitebark pine is confined to the above 8500 feet limits of this strip, which ranges from 7000 to 9500, with lodgepole, alpine fir, Douglas fir and Engelmann spruce at the lower limits.

Secondary bark beetles, windthrow, snowbreak and other sources of injury have killed about 1.12 trees per acre, or about 75 percent as much as had been killed directly by the mountain pine beetle. Whitebark pine showed only .19 tree per acre, or 5 percent as much loss from the same source, but many trees suffered heavy damage due to wind breakage of limbs. Due to the light losses in the lodgepole pine type, mountain pine beetle activity has made no material change in the stand. Although the whitebark pine stands have been decidedly reduced in number of trees per acre, there is no evidence of replacement by any tree species.

TARGHEE CHECK STRIP

The mountain pine beetle infestation on the Targhee National Forest became sufficiently heavy in 1931 to cause considerable loss. An estimate of trees killed by that insect on the check strip from then until 1934, when the strip was established, indicates a loss of slightly over 4 trees per acre. Trees killed subsequently and until 1940 have been determined by annual surveys. The estimates of annual loss are as follows:

Table 8 - Mountain pine beetle infestation in lodgepole pine on Targhee check strip, 1931 to 1940
Acreage of strip = 40

Year	Infestation Per acre	Infestation Total
1931 *	.86	34
1932 *	1.19	48
1933 *	2.17	87
1934	9.98	399
1935	11.97	479
1936	6.58	263
1937	1.17	47
1938	.27	11
1939	.35	14
1940	.07	3
	34.61	1,385

* Estimate based on general infestation over forest.

From the preceding table it is seen that 1,385 trees have been killed on this strip by mountain pine beetle and secondary bark beetle attack. From the figures given it is also seen that practically all these losses occurred during the period from 1931 to 1937.

Even as early as 1935, when the greatest losses of any one year occurred, secondary insects were beginning to play a part in the destruction indirectly brought about by the amountain pine beetle. Loss due to damage from fall of bark-beetle-killed trees began in 1938. The loss from secondary bark beetle activity and the percent this is of total kill is shown in table 9.

Table 9 - Indirect losses as a result of a mountain pine beetle outbreak - Targhee check strip 1935-40

Trees killed by secondary bark beetles			Total trees killed	Percent killed by sec.	Windfall of bark-beetle-killed trees	Green trees killed or damaged by them	Green wind-thrown
Date	Unat. green	Prior D.m. att.					
1935	5	--	479	1	--	--	--
1936	20	47	263	25.5	--	--	--
1937	13	32	47	95.7	--	--	--
1938	1	10	11	100	4	--	--
1939	9	5	14	100	48	2	5
1940	3	--	3	100	176	4	6

Inspection of the preceding table reveals some of the destruction indirectly attributable to the mountain pine beetle. Previously undamaged green trees numbering 51, or 1.27 per acre, were killed during the period from 1935 to 1940. In addition, trees green-sided or that had pitched out mountain pine beetle attacks had been overcome by the secondaries to the number of 94, or 2.35 per acre. While the green-sided trees would have been of little if any merchantable value, they would have helped, for a short time at least, to preserve a much-needed crown cover, reduce windthrow and decrease snowbreak of the remaining living, smaller trees.

Fire hazard and maintenance difficulties can be visualized by noting the number of fallen bark-beetle-killed trees. The first of these fell in 1938, followed by increasing numbers in the next two years. The data concerning them are given in table 10.

Table 10 - Windthrown mountain-pine-beetle-killed trees on Targhee check strip to 1940

Date windthrown	Year of attack: Pre 1934	34	35	36	37	38	39	40	Not known	Total
1938	--	4	--	--	--	--	--	--	--	4
1939	23	18	2	5	--	--	--	--	--	48
1940	146	18	6	2	--	--	--	--	4	186
Total	169	40	8	7	--	--	--	--	4	238
Trees killed	169	399	479	263	47	11	14	3	--	1,385
Percent windthrown	100	10	1.7	2.7	--	--	--	--		17.2

From the data in table 10 it is seen that windfall of bark-beetle-killed trees began the fourth year after attack and was considerable after the seventh. A factor which may have caused earlier windthrow on this strip is the large amount of wood cutting which has been in progress on the area. Wood cutters fell the tallest, larger trees, removal of which would have the most influence in opening up the stand to windthrow of the remaining trees.

Change in type following heavy loss of lodgepole pine is illustrated from a .1 acre plot taken on the strip. This plot was in a comparatively open stand and prior to insect attack supported 24 mature lodgepole pine and 2 Douglas fir. The lodgepole pine have been killed, but the Douglas fir are alive and thrifty. Reproduction present on the plot gives an index of the future crop. In table 11 are shown stand compositions prior to and following the bark beetle outbreak.

Table 11 - Stand on .1 acre plot preceding and subsequent to mountain pine beetle outbreak - Targhee

1938

Mature trees prior to outbreak		Seedlings and small trees subsequent to outbreak								Mature trees
		Hgt. in								
LP	DF	inches	0-6	6-18	18+	Total	0-6	6-18	18+	Total	DF
Number 24	2		4	23	101	128	7	33	68	108	2
Percent of total 92.3	7.7				54			46			

From the preceding data, Douglas fir gives evidence of comprising about 50 percent of the future stand or about six times the numerical composition prior to the mountain pine beetle outbreak. These conditions seem to prevail over this general area wherever the altitude is approximately the same (5100), as on this strip.

The change which has occurred on this plot reflects to a greater or less degree the changes in stand composition which are occurring wherever the lodgepole pine at other than high elevation has been largely destroyed. The invading tree species may not always be Douglas fir, but lodgepole pine comprises a smaller proportion of the future stand.

SAMPLE PLOT A

This quarter-acre plot on a ridge at an elevation of about 5400 feet on the east fork of the Bitterroot River was originally covered with an excellent stand of mature lodgepole pine timber. On that stand of 80 lodgepole pine, 3 inches or larger in diameter, only 12 undamaged trees remain. They are of the smaller diameter classes. Stand conditions on the plot at the time of the outbreak and in 1940 are given in table 12.

Table 12 - Effect of the mountain pine beetle outbreak on Sample Plot A - Bitterroot National Forest 1940

1.	Number of living lodgepole pine over 3 inches d.b.h. present on the plot in the spring of 1923	80
2.	Number of preceding trees undamaged in fall of 1940	12 1/
3.	Green-sided trees living but unfit for timber	4
4.	Basal area of lodgepole pine in excess of 3 inches d.b.h. in spring of 1925	42.6 2/ sq. ft.
5.	Basal area of remaining living lodgepole pine of above trees in fall of 1940	3.5 3/ sq. ft.
6.	Percent 5 is of 4	8.1
7.	Other trees on plot not included in above figures	
	(a) Douglas fir 8, lodgepole pine 1	
	(b) Basal area of	
	Douglas fir	1.30 sq. ft.
	Lodgepole pine	.07 " "
8.	Estimated area of 8 Douglas fir in 1925	.65 " "
9.	Change in percent of basal area of DF to total stand from 1925 to 1940	1.5 to 26.7
10.	Change in percent of number of DF to total stand from 1925 to 1940	9.0 to 38.1

1/ Includes one tree slightly bent by falling mountain-pine-beetle-killed tree.

2/ Basal area data are for 1925, but first trees were killed on plot in 1923.

3/ Includes growth in basal area from 2.8 to 3.5 during period from 1925 to 1938.

Inspection of table 12 reveals some of the changes which have taken place in the plot as the result of the mountain pine beetle outbreak. Commercial timber is now practically nonexistent, the largest undamaged tree being 10 inches in diameter. The trees remaining are 15 percent of the original number, but the basal area is only 8.1 percent and that includes growth between 1925 and 1938.

At the time the plot was laid out in 1925, Douglas fir is estimated to have comprised only 1.5 percent of the total basal area on the plot. The destruction of so much of the lodgepole pine has decidedly changed the tree species content of the plot. In number of trees the change in Douglas fir has been from 9.0 to 38.1 percent and the basal area raised to 26.7 percent. While this is a decided type change, it does not reflect the even greater change as shown by reproduction on the plot. These data are given in table 13 from three small plots, showing reproduction, and from two very small plots for seedling counts, all within plot A.

Table 13 - Stand on three sub-plots on sample plot A - Bitterroot National Forest - data as of 1938

Area of plots 20' x 20', 20' x 20', and 20' x 84', or a total of 2,480 square feet = .057 acre

Contents of Plots

Hgt. of trees in feet	Tree species LP	DF	WbP	Totals
Under 1/2	--	5		5
1/2 - 1	5	15		20
1 - 2	8	7	1	16
2 - 3	12	2		14
3 - 4	2	1		3
4 - 5	1	4		5
5 - 10	9	9		18
10 - 15	--	1		1
15 - 20	1	--		1
	38	44	1	83
Percent of total	45.8	53.0	1.2	

Seedlings on two very small plots

DF	LP	WbP	Size of plots
54	--	--	3' x 3'

From table 13 it is seen that Douglas fir comprises over half the reproduction and all of the seedlings. Exclusive of seedlings there are now present on the plot 51 lodgepole pine, 52 Douglas fir, and one whitebark pine, larger than seedlings. While the lodgepole pine comprises better than 75 percent of the basal area of trees over 3 inches d.b.h., those trees are of the older age classes and not making the vigorous growth of the Douglas fir. From the evidence now present on the plot the future timber crop will be made up of at least 50 percent Douglas fir, with the possibility of a much greater amount.

Of the 64 bark-beetle-killed trees on the plot, 43 have been uprooted, of which 4 have lodged against other trees. The average length of time from kill to fall for the uprooted trees is 10.8 years. By the time the remaining 21 trees are windthrown this figure will be raised. The average time since attack of the remaining dead standing trees was 11.6 years in 1940. On the exposed ridge on which this plot was located the first trees fell 6 years after death and 21 had fallen in the next four years. In the succeeding five years another 19 had fallen. No examinations of the plots have been made since 1940.

The history of this plot has been unusual in that the period of kill of trees by the mountain pine beetle lasted for 9 years, beginning in 1923 and ending in 1932. It has been the writer's observation that serious losses in this timber type have been quite light after six years from invasion of an area by an epidemic of this beetle.

SAMPLE PLOT B

This quarter-acre plot, also established in 1925, is only a few chains south of plot A and at the same elevation, about 5400 feet. Although on the same ridge, it was largely western yellow (ponderosa) pine instead of lodgepole pine, but contained a few of the latter species. Of the original 30 ponderosa and 8 lodgepole pine in the plot in 1925, only one living tree remains, a 3-inch defective ponderosa pine. Thus, less than 3 percent of the original number of trees over 3 inches d.b.h. on the plot are alive. In basal area the surviving tree is only .1 percent of the "pre-outbreak" amount.

Deterioration of mountain-pine-beetle-killed western yellow pine is much more rapid than lodgepole. The thick bark seems to promote decay of both sapwood and heartwood. Where the material is in contact with the ground and of small diameter, rotting is well advanced. Material from which the bark has fallen and which is off the ground shows decidedly less decay. Lodgepole pine under the same conditions exhibits much less decay.

At the time this plot was established there were many Douglas fir on the plot. In 1938 there were 29 trees of this species over 4 inches in diameter. No record was made of their diameter in 1925, but in 1938 they averaged 9.3 inches d.b.h. and had a basal area of 16.25 square feet. The basal area of the pines on the plot in 1925 was 32.82 square feet, so

the 1938 basal area of Douglas fir was almost exactly half that of the former pine stand. Reproduction and seedlings show only two ponderosa pine undamaged on the plot, while there are six Douglas fir. Very small plots within the plot contain only Douglas fir seedlings. It can be seen from the preceding discussion that in this former predominantly ponderosa pine plot valuable timber has practically disappeared, to be replaced by an almost pure stand of Douglas fir. The pre-infestation and present stand data are summarized in table 14.

Table 14 - Stand prior to infestation and at present on sample plot B - East Fork - Bitterroot National Forest

1.	Change in number of living western yellow pine on plot from 1925 to 1940	30 to 1
2.	Change in number of living lodgepole pine on plot from 1925 to 1940	6 to 0 [1]
3.	Douglas fir on plot now	29 [2]
4.	Reproduction on two sub-plots on plot totalling	800 sq. ft.
	Douglas fir	6
	Western yellow pine	3 [2]
5.	Western yellow pine on plot not included when plot was established	8 [3]
6.	Change in basal area of lodgepole and western yellow pine from 1925 to 1938	32.82 to .05
7.	Present basal area of Douglas fir in excess of 4" d.b.h. now on plot	16.25 [4]

1/ Trees 3" or larger when plot established.

2/ Trees 4" or larger at present time.

3/ Four undamaged, 4 damaged and unfit for future timber.

4/ Of this, 2.37 damaged too much for future timber.

SAMPLE PLOT C

This plot, also established in 1925, differs from plot A chiefly in site. In contrast to the high ridge-top site of plot A, exposed to wind and excellent light conditions, plot C is within a few feet of a creek bottom at an elevation of about 5100 feet. There, light is less and the plot well sheltered from wind, so as to favor excellent height growth of the timber. The site is steep, well-drained, and east-facing.

Losses on this plot began in 1924 and were the heaviest that year. Up to 1940 only 11 of the original 65 living lodgepole pine on the plot were still alive.

The changes which have taken place are summarized in table 15.

Table 15 - Changes in lodgepole pine stand on plot C

1.	Change in number of living lodgepole pine from 1925 to 1940	65 to 11
2.	Percent number of survivors is of former stand	16.9
3.	Change in basal area of living lodgepole pine from 1925 to 1940	31.27 to 2.81
4.	Percent basal area of surviving lodgepole pine is of former stand	9.0
5.	Change in average d.b.h. of lodgepole pine from 1925 to 1940	8.9 to 7.3 1/
6.	Change in DF over 3" d.b.h. on plot from 1925 to 1940 2/	18 to 13
7.	Change in DF from 1" to 3" d.b.h. on plot from 1925 to 1940	31 to 3
8.	Reproduction on plot 20' x 20' -	ES 1, DF 5, WbP 9, LP 5
9.	Seedlings on 3' x 3' plot =	DF 5

1/ Includes growth from 1925 to 1940.

2/ Diameters are as of 1938.

Totalling the undamaged green trees on the plot reveals an equal number of lodgepole pine and Douglas fir over 1 inch in diameter breast high. The remaining trees are lodgepole over 2 inches larger in diameter than the Douglas fir and are tall and slim but with small crowns confined to the topmost few feet of the tree. It remains to be seen if wind or snow will cause their overthrow in the opened-up stand. Only 23 of the 54 killed trees on the plot had fallen up to 1940, so further opening up of the stand, with consequent probable windthrow and injury of remaining young trees due to falling insect-killed trees, may be expected. The Douglas fir are shorter trees with long crowns and are making vigorous growth. Many of the small Douglas fir have been damaged by falling trees. On that basis we may expect that more will be damaged before all the trees have fallen.

Prior to the outbreak, lodgepole pine comprised at least 75 percent of the trees present on the plot. Present conditions indicate that percentage will be reduced to between 30 and 40, with Douglas fir in about the same ratio and whitebark pine, alpine fir and Engelmann spruce comprising the rest. The lack of whitebark pine in mature stands inclines the writer to the belief they may die out at an early age in the normal dense forest at this low elevation. However, under the present opened-up stand conditions they may mature.

SAMPLE PLOT D

Located on the west side of a high ridge at an elevation of about 6000 feet, this plot has a site differing chiefly from that of plot A in that it is somewhat higher, is on a gentle west slope, is more open, and less exposed to wind. The trees are quite uniform in height and diameter, but average about 10 feet shorter than those on plot A. Only 43 lodgepole pine over 3 inches in diameter comprised the stand on this plot. Losses to and status of the stand on the plot in 1940 are given in table 16.

Table 16 - Sample Plot D - East Fork - Bitterroot National Forest - 1940

Losses to and present status of stand

1.	Change in number of lodgepole pine over 3 inches d.b.h. from 1925 to 1940	43 to 8 [1]
2.	Percent surviving lodgepole pine are of original stand	18.6
3.	Change in basal area from 1925 to 1940	23.93 to 3.89 [2]
4.	Percent remaining lodgepole pine basal area is of original stand	16.3
5.	Percent of dead trees uprooted to 1940 (9 of 32)	28.1
6.	Number and basal area of DF over 3 inches d.b.h. on plot	10 and 13.95
7.	Number of DF and LP in 1" to 3" classes on entire plot	6 and 8
8.	Number and species of reproduction on 20 x 20 plot	6 and DF
9.	Number and species of seedlings on 3 x 3 plot	72 and DF
10.	Number and species of reproduction on entire plot	106 & DF 5 and LP

In spite of considerable survival of lodgepole pine, this species amounts to only 21.9 percent of the total basal area of living timber on the plot. Prior to the outbreak lodgepole pine comprised in excess of 75 percent of the basal area and about the same percentage of trees. Of the reproduction on the plot only 13, or about 10.4 percent, of the 125 are lodgepole pine and the rest are Douglas fir. All seedlings noted on the plot were Douglas fir. Again we find the latter species practically "taking over" the area, but lodgepole pine persisting in a minor role.

Probably as a result of the open nature of the stand on this plot, but in some measure to the shorter trees and the few that had fallen to 1940, damage to the remaining timber on this plot has been negligible.

1/ Does not include 3 green-sided trees.

2/ Includes growth from 1925 to 1940.

SAMPLE PLOT E

In locating this plot an effort was made to secure conditions representative of a lodgepole pine stand at high elevation on an east exposure. Owing to the heavy stand, the plot area was reduced to 1/16 acre instead of 1/4 acre as in the other plots. Although the average diameter of the 43 trees on the original plot was only 6.8 inches, the trees were quite tall, had little taper and small crowns.

To 1940, trees killed numbered 28. The average diameter of 6.9 of the remaining trees is about the same as that of the original stand. In spite of the early attack of many of the trees on this plot, the exposure to wind, and the slimness of the trees, only 54 percent had been uprooted by 1940. The past and present status of the timber on this plot is shown in table 17.

Table 17 - Sample Plot E - East Fork - Bitterroot National Forest - 1940

Losses to and present status of stand

1.	Change in number of lodgepole pine over 3 inches d.b.h. from 1925 to 1940	43 to 15
2.	Percent surviving lodgepole pine are of original stand	34.9
3.	Change in basal area from 1925 to 1940	11.16 to 4.28 1/
4.	Percent remaining lodgepole pine basal area is of original stand	38.3 1/
5.	Percent of dead trees uprooted (15 of 28) to 1940	53.6
6.	Number and basal area of Douglas fir over 3 inches d.b.h.	None
7.	Number of DF and LP in 1" to 3" classes on entire plot	None
8.	Number and species of reproduction on 20 x 20 plot	1 LP and 1 DF
9.	Number and species of reproduction on entire plot	3 DF, 1 LP, 3 AF, and 1 WbP
10.	Number and species of seedlings on 3' x 3' sub-plot	None

1/ Includes growth to 1938.

This plot is located at the highest elevation (7100 feet) of any of the plots. It probably exceeds the height of the next highest plot by at least 1100 feet and of the lowest by about 2350 feet.

Contrary to conditions on the plots at lower elevation, there is no evidence that Douglas fir is going to "take over" this area. However, that species is present in considerable quantity about 1000 feet from and 100 feet lower than the plot.

Losses have been comparatively light, possibly due to the somewhat smaller diameter of the trees. Small trees are known to be more resistant to attack than those of larger diameter. It is problematical if the present stand of lodgepole pine can maintain itself due to the severe opening up of the stand and liability to windthrow of the remaining tall, slim trees.

There are no present indications that the stand type will be materially changed.

SAMPLE PLOT F

This plot was established in 1926 on a river-bottom site at the foot of a steep north-facing slope. Elevation of this plot is approximately 4750 feet, the lowest of the plots. The mountain pine beetle caused the least loss on this plot of any, although there were heavy losses nearby. The changes and present status of the timber on this plot are shown in table 18.

Table 18 - Sample Plot F - East Fork - Bitterroot National Forest - 1940

Losses to and present status of stand	
1. Change in number of lodgepole over 3 inches d.b.h. from 1926 to 1940	64 to 36
2. Percent surviving lodgepole pine are of original stand	56.2
3. Change in basal area from 1926 to 1940	38.98 to 16.41 1/
4. Percent remaining lodgepole pine basal area is of original stand	42.1
5. Percent of dead trees uprooted (8 of 28) to 1940	28.6
6. Number and basal area of DF over 3 inches d.b.h. on plot	4 and 3.51 1/
7. Number of DF and LP in 1" to 3" d.b.h. classes on entire strip	None

1/ Includes growth to 1935.

8. Number and species of reproduction on 20 x 20 plot — 19 DF, 16 LP

9. Number and species of seedlings on 3 x 3 plot — 10 and DF

Lodgepole pine still occupies a dominant place in this stand in spite of the loss to that species of over half the original basal area. Douglas fir increased in basal area of living trees from about 8 percent in 1926 to 17.6 percent in 1938. It is apparent from present indications that Douglas fir will not become the dominant species on this plot prior to the maturity of the present lodgepole pine stand on the plot, and as the latter only average 9.1 inches d.b.h., that time is quite remote. It must be pointed out, however, that Douglas fir predominates in reproduction and comprises all seedlings noted on the plot.

DISCUSSION

Timber-managing agencies are concerned with the effects of a mountain pine beetle infestation. The major considerations are timber loss, maintenance costs of communication and administration following outbreaks, fire hazard, and changes in stand composition. Conditions found by the writer will be discussed insofar as data are available.

The following statements as to stand composition changes must be considered as merely indicative. They are based only on conditions found up to 1940. In many cases the indicated future stand is composed of seedlings and small reproduction, which may not be a true picture of the composition even 10 years from now, let alone the final stand. It is quite possible that the stands are still in a state of change, which may not cease for a number of decades.

Replacement of lodgepole by other timber species was reported by H. R. Flint[1/], in which he noted, six years after cessation of an outbreak in northern Montana, that "a strikingly large percentage is Douglas fir." This applied to seedlings 5 years of age and younger.

Where losses to lodgepole pine have been light in mixed-type stands of low altitude, no great change in stand composition has occurred. Although the trees killed were of the larger-diameter classes, many of those diameters remain. The stand of merchantable lodgepole has merely been reduced. Timber species immune to mountain pine beetle attack become a more or less larger part of the total stand contents, thus hastening the conversion toward a climax forest type.

1/ Applied Forestry Notes, Number 54, November 1924. "Various Aspects of the Insect Problem in the Lodgepole Pine Region." H. R. Flint.

Falling dead trees will slightly increase maintenance of communications, administration may be slightly more difficult, timber sale income or possibilities of sale somewhat reduced, and fire hazard slightly increased.

For light losses in pure lodgepole pine stands at low altitude no plot or strip data were available. The writer has observed, however, that whenever the stand opens up slightly and Douglas fir large enough to produce seed are present, reproduction of that species comes in. The latter, however, would not assume any commercial importance on such areas until after the maturity of the present lodgepole pine stand. Timber losses, maintenance costs and administration should be but little different from those in a mixed type.

Light losses at high altitude are illustrated by the Squaw Creek strip. Merchantable timber has been killed, but as the stand is of mixed type the loss is not serious and the stand composition only changed to the extent that the ratio of immune species to lodgepole pine is increased. Where whitebark pine is present it usually suffers a higher ratio of loss than lodgepole pine. Other factors are but slightly changed.

Where losses are heavy the stand is much more affected. Mature timber of the larger diameter classes may be eliminated from the stand. In a practically pure lodgepole type at low elevation Douglas fir and alpine fir may comprise a large and occasionally the greater part of the reproduction. In such cases the indicated future type is almost completely changed, with lodgepole pine comprising but a small part of the future stand. Occasionally, however, where but few trees are left in the stand and the site is warm, lodgepole comes in sufficiently to restock the area.

"Jack-straw" conditions of fallen trees, where timber loss has been heavy, create a high fire hazard which persists for many years. Maintenance of roads, trails and telephone lines under such conditions is expensive, administration of such areas difficult, and income practically nothing.

Data from ponderosa pine stands are confined to one plot. On it only three 1- to 3-inch trees of the former heavy stand of that tree species remain alive. The lodgepole pine that was present on the plot is also dead. Douglas fir trees and reproduction have "taken over" the plot and will apparently constitute the entire future stand.

Ponderosa pine deteriorates much more rapidly than lodgepole pine. The tops have been broken out of nearly all the trees and where they are in contact with the ground, rotting is well advanced. Sapwood of the standing bases of the trees is rotten, but much of the heartwood of the larger trees was still sound in 1940. Fire hazard from ponderosa pine will be less and of shorter duration than in the lodgepole pine type.

Areas near the upper limits of the lodgepole pine type, which show heavy losses in an almost pure stand, have comparatively few seedlings and reproduction. Scattered Douglas fir, alpine fir, Engelmann spruce and whitebark pine are to be found, but too few to indicate what the future stand may be. There has been little tendency up to the present toward the area being "filled in" by Douglas fir.

From the data secured to the present time, it is seen that increased maintenance costs due to windthrow of beetle-killed trees can be expected within five years after trees have been killed. The average age of fall of the trees is between seven and eight years for all strips and plots, but this average is expected to be raised, as bark-beetle-killed trees are known to stand for at least 15 years.

The widespread outbreak that devastated such vast areas of lodgepole pine in central-eastern Idaho and southwestern Montana has decreased to a fraction of its former severity. Observations made in 1940 were over a sufficiently wide area on which to base a conclusion. On the main Beaverhead Forest an exhaustive search was necessary to find even one mountain pine beetle. Light outbreaks were still present in lodgepole and whitebark pine in the Blacktail drainage and the Gravelly Range on the Beaverhead. Whitebark pine was suffering considerable but decreasing loss in the Tobacco Root Mountains and on the main Gallatin Forest.

FURTHER WORK

Examinations of these plots and strips should continue for the following reasons:

(1) To learn the duration of the period when bark-beetle-killed trees fall.

(2) To determine the amount of and period during which indirect losses occur.

(3) For measurement of changes in rate of growth of remaining living trees.

(4) To determine changes in stand composition.

To secure these data, examinations at five-year intervals would show the general trend but would not show any abnormality that might occur due to exceptional weather conditions, local infestations of defoliators, timber-cutting operations, etc. It is the opinion of the writer that to secure the above data an annual or at least biennial examinations should be made. If conditions permit, it is planned to make an examination in 1943. Increment cores of the trees on the plots and from adjoining areas where no losses have occurred should also be secured in order to note any change in diameter growth.

Remeasurement of all living trees on the plot should also be made in order to show increases in diameter.

SUMMARY

Up to 1940, examinations have been conducted for from 8 to 15 years on permanent sample plots and strips established to study the effect of a mountain pine beetle infestation. These plots and strips represent not only pure lodgepole pine stands but various associations of other timber species with lodgepole. One plot predominates in western yellow pine and a second contains pure whitebark pine over part of its area. Losses on these plots and strips vary from very light on some to complete loss of all merchantable timber on others.

Losses as the result of a mountain pine beetle outbreak are classified as direct and indirect. The first includes only trees whose death has been due primarily to attack of the mountain pine beetle. Indirect losses include those caused by secondary insects and all mechanical injury resulting from the outbreak.

A mountain pine beetle outbreak was found to complete its destruction on an area in about 6 years, but may remain as long as 9 years. Indirect losses persist for an indefinite period, but are varied and heavy during the years when fall of the bark-beetle-killed trees is heavy. Indirect losses are heaviest in the smaller-diameter trees, and while the number killed may exceed direct losses by the mountain pine beetle, the basal area is decidedly less.

Maintenance costs of roads, trails, and telephone lines, because of windthrown trees, are likely to show annual increases for a number of years, beginning four years after trees are killed. Data indicating the period when these costs will remain high are incomplete. Fire hazard is increased and will remain high for many years on areas where losses have been great.

Stand composition is but little affected where losses due to bark beetles are light. This applies to both pure and mixed stands. Tree species other than lodgepole pine become a much larger part of the seedlings and reproduction when losses are heavy, except at high elevation. The replacing species are Douglas fir, alpine fir, and Engelmann spruce, the first usually far exceeding the total of the other two. Where very little crown canopy is left, due to almost complete loss, lodgepole pine may adequately stock the area.

At high elevation no replacement has been observed in either lodgepole or whitebark pine. It is possible these areas are slow to "seed in." This applies whether the losses have been light or heavy.

Stand changes are probably still occurring and present reproduction and seedlings must not be considered as definite indications of the future stand.